Europe's braking technology conference & exhibition

17-21 May 2021 Online

Preliminary Programme (All Sessions)

Thanks to the EuroBrake sponsors:

brembo
HORIBA Automotive Test Systems
LINK
oerlikon
TEIJIN Human Chemistry, Human Solutions
ASK
fagorederlangroup
RENK

Organisation

Steering Committee

Jan Münchhoff – Audi, Chairman EuroBrake 2021

Harald Abendroth – Consultant

David Barton – University of Leeds

Yannick Desplanques – University Lille

Klaus Jäckel – Daimler Truck AG

Georg Ostermeyer – TU Braunschweig

Ludwig Vollrath – Formula Student Germany

Roberto Tione – WABTEC-Faiveley

Gemma Wilkins – FISITA – EuroBrake 2021 Project Manager

EuroBrake Student Opportunity Programme 2021 Working Group

Kai Bode – Audi

Jens Bauer – Continental

M.Sc. Jacek Kijanski – TU Braunschweig

Fabian Limmer – University of Leeds

Nils Perzborn – ZF Group

Hannes Sachse – IDIADA FAhrzeugtechnik

Aaron Völpel – VW

Hayley Millar – FISITA

Advisory Board

Jayashree Bijwe – Indian Institute of Technology

Stefan Dörsch – DB Systemtechnik

Philippe Dufrénoy – University Lille

John Fieldhouse – JDF Consulting

Peter Filip – Southern Illinois University Carbondale

Johannes Gräber – Knorr-Bremse - Systeme für Schienenfahrzeuge

Theodoros Grigoratos – European Commission,

Joint Research Centre

Takashi Kudo – Akebono Brake Industry Co.

Ralph Lauxmann – Continental AG

Michael Lingg – VW

Loïc Lelièvre – Flertex Sinter

Roy Link – Link.

Luca Martinotto – ITT Friction Technologies

Manfred Meyer – ZF TRW

Jiliang Mo – Southwest Jiaotong University

Parimal Mody – Brake and Friction Expert

Rainer Müller-Finkeldei – Daimler Truck AG

Tony Nicol – Meritor

Masaaki Nishiwaki – Kanagawa Institution of Technology

Franck Poisson – SNCF

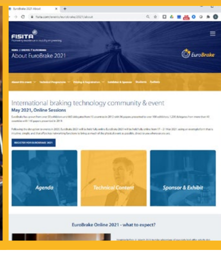
Seong Kwan Rhee – SKR Consulting, LLC

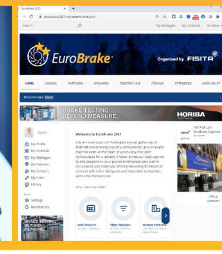
Yukihiro Shiomi – Toyota Motor

Fabio Squadrani – Applus IDIADA

Stephan Stass – Robert Bosch

The EuroBrake Advisory Board consists of representatives from major companies and research institutions that lead the field in braking technology today. The Advisory Board provides strategic advice and helps to ensure that EuroBrake continues to meet the needs of the international braking community.




Your invitation to EuroBrake 2021

EuroBrake is delighted to announce the full series of technical and panel sessions you have come to expect at the physical event, plus much more – all in a virtual environment.

There will also be unique networking opportunities at EuroBrake 2021.

New for 2021, the EuroBrake Virtual Content Delivery (VCD) platform will showcase partner companies and provide unique networking opportunities for a truly immersive online experience.

Through the online event platform, attendees can message, video call, and post to the forums, and build a personal agenda and experience. The platform can suggest people and companies with similar interests and products to improve networking opportunities.

Our virtual exhibition package enables you to showcase your braking products, services, innovation & technical expertise, and connect you to a highly relevant audience of engineers and executives. All package elements are delivered online via the EuroBrake website and the EuroBrake Virtual Content Delivery platform (VCD), where partner companies will be showcased to delegates within technical content and benefit from unique 'intelligent networking' functionality. Contact Nadine Lloyd at sales@fisita.com for more info

What to expect at EuroBrake 2021

Register now to gain access to our full back catalogue of technical papers from EuroBrake 2012 up to last year.

We will send your personal link to access the virtual event site on 4 May 2021. To get the best experience from the virtual event, ensure your profile is fully updated and that you have selected all the options that you are offering or interested in at the event.

In the virtual event site, you will be able to:

- Update your profile to show people what you are interested in at EuroBrake
- Tell people if you have a product or some research to share
- Set your personal agenda with times you are available to meet/network and times you are busy
- Select all the sessions you wish to attend and build your personal agenda
- Download technical papers, posters, and videos
- Private message other attendees and set up videocalls within the platform (including group calls)
- Network with speakers
- View special exhibitor and sponsor content and connect with these groups via messaging and video calls
- Chat to colleagues in the open chat forums
- Watch sessions back on-demand if you missed them live

Students and academics can register for £25 and access all the technical sessions and content!

Go to the website for more info and to register

Preliminary Technical Programme

EuroBrake 2021 will be held virtually from Monday 17 May to Friday 21 May. Registered attendees will receive a link to the virtual event site on 4 May 2021 so that they can complete their profiles and begin to plan their week. The following pages list out the preliminary programme of sessions that will be held during the week, with a summary of activities below that includes the EuroBrake Student Opportunity (ESOP) sessions.

Monday 17 May 2021
(All times in CEST)

09:00–09:30 ESOP Intro

10:00–11:00 **EuroBrake Kick-Off: Meet the Key Players**

11:00–12:00 ESOP Q&A

12:00–13:40 **Technical Sessions**

- ACB – Advanced Coatings for Brake Components
- AMM – Advanced Manufacturing and CO2 Mitigation

14:00–14:30 Meet the Speakers

15:00–16:40 **Technical Sessions**

- CLF – Challenges around Long-Life Friction Couples
- IBR – Innovative Brake Rotors

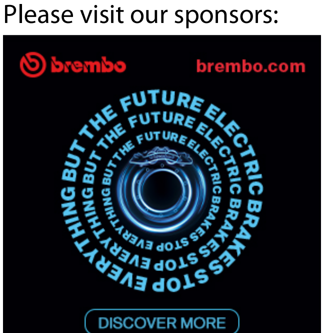
17:00–17:30 Meet the Speakers

14:30–15:00 ESOP Intro US

17:00–18:00 ESOP Q&A

17:30–19:30 **Poster Session**

Please visit our sponsors:



Tuesday 18 May 2021
(All times in CEST)

09:00–10:15 **EuroBrake Keynotes**

- Duncan Kay, UK Department for Transport: *Regulation Activities for Brake Emissions*
- Dr.-Ing. Stefan Dörsch, DB Sytemtechnik: *What can the automotive braking community learn from rail, and vice versa? Some thoughts about electric cars and autonomous driving*

10:00–11:00 ESOP Roundtable 1

10:00–11:00 ESOP Surgery 1

11:00–12:40 **Technical Sessions**

- Fundamentals of Friction
- Brakes and Components in EV

13:00–13:30 Meet the speakers

14:00–15:40 **Technical Sessions**

- Intelligent Braking and Braking Control (Rail)
- Environmentally Friendly Formulations

16:00–16:30 Meet the speakers

16:30–18:30 **ISO Session**

17:00–18:00 ESOP Roundtable 2

17:00–18:00 ESOP Surgery 2

Wednesday 19 May 2021
(All times in CEST)

08:00–09:00 ESOP Roundtable 3

09:00–10:40 **Technical Sessions**

- Brake Emissions Macroscopic Part 1
- Materials, Manufacturing and Design (rail)

11:00–11:30 Meet the speakers

11:30–13:10 **Technical Sessions**

- NVH- Vehicle Applications
- Brake Emissions Macroscopic Part 2

13:30–14:00 Meet the speakers

14:00–15:00 ESOP Roundtable 4

14:00–15:00 ESOP Surgery 3

15:00–16:40 **Strategy Panel**

- Chassis System Approach – New Ways of Co-operating between OEM & Tier 1
  Chairs: Jan Münchhoff, AUDI; Georg-Peter Ostermeyer, TU Braunschweig

17:00–18:00 ESOP Surgery 4

Thursday 20 May 2021
(All times in CEST)

08:00–09:00 ESOP CV session 1

09:00–10:40 **Technical Sessions**

- Simulation, Testing, Innovative Development Processes (rail)
- NVH- Fundamentals

11:00–11:30 Meet the speakers

11:30–13:10 **Technical Sessions**

- Brake Emission Microscopic Level

13:30–14:00 Meet the speakers

14:00–15:40 **Rail Panel**

16:00–17:00 ESOP CV session 2

16:00–17:00 **Open Seminar**

Friday 21 May 2021
(All times in CEST)

09:00–10:40 **Technical Sessions**

- Brake Control
- Innovative Raw Materials

11:00–11:30 Meet the speakers

12:00–13:40 **Technical Sessions**

- High Performance Products
- Advances in Rotor Technology

14:00–14:30 Meet the speakers

15:00–16:00 ESOP CV session 3

16:00–16:30 ESOP Wrap Up

Monday, 17 May 2021

12:00–13:40 CEST Technical Sessions

ACB – Advanced Coatings for Brake Components

Chair: Refaat Malki, Meritor
Co-chair: Suman Shrestha, Keronite

EB2021-STP-020

Preliminary Comparisons of Particulate Emissions Generated from Different Disc Brake Rotors

Asmawi Sanuddin, David Barton, Peter Brooks, Carl Gilkeson, Shahriar Kosarieh, (University of Leeds).

Suman Shrestha, (Keronite International).

EB2021-STP-012

Lab-Scale Anodization of Prototype Brake Calipers

Federico Bertasi, Marco Bandiera, Alessandro Mancini, Arianna Pavesi, Andrea Bonfanti, (Brembo S.p.A.).

Massimiliano Bestetti, (Politecnico di Milano).

EB2021-MDS-003

Novel Computationally Designed Brake Disc Coatings for Thermal Spray and Extra High-Speed Laser Cladding

Eng. Hossein Najafi, Eng. Arkadi Zikin, (Oerlikon).

Cameron Eibl, (Oerlikon).

Franco Arosio, Thilo Krah-Tomala, (Oerlikon).

14–14:30 CEST Meet the Speakers

Please visit our sponsors:

Monday, 17 May 2021 (cont.)

12:00–13:40 CEST Technical Sessions

AMM – Advanced Manufacturing and CO2 Mitigation

Chair: Wolfgang Schröer, DRiV
Co-chair: Karsten Fischer, Fischer Consulting

EB2020-MDS-011

Fabricated Brake Pads Using Non-firing Ceramics

Masato Furuta, Yukio Nishizawa, Masaru Yagihashi, (ADVICS.).

Masayoshi Fuji, (Nagoya Institute of Technology).

EB2020-MFM-004

CO2 Foot Print Reduction in Brake Pad Industry

Karsten Fischer, (Fischer Consulting).

EB2020-MFM-010

Friction Pad Manufacturing with Integrated Quality Control

Karsten Fischer, (Fischer Consulting).

Andreas Meyer, (AUT-FIT Automatisierungstechnik).

EB2021-STP-014

Crack Detection in Friction Material of Brake Pads

iLse Clijsters, Alex Van den Bossche, (GrindoSonic).

14–14:30 CEST Meet the Speakers

15:00–16:40 CEST Technical Sessions

CLF – Challenges around Long-Life Friction Couples

Chair: Sebastian Fischer, Continental AG
Co-chair: Agusti Sin, ITT Friction Technologies

EB2021-EBS-012

Longlife Friction Couples

Agusti Sin, (ITT Friction Technologies).

Sebastian Fischer, (Continental).

EB2021-MDS-006

Lifetime Protection of Iron Casted Brake Discs for Electric Vehicles through Advanced Heat Treatment Technology

Franco Arosio, (Oerlikon).

Ingo Lange, (Oerlikon).

EB2020-STP-016

Changing Properties of Brake Pads and Discs at Room Temperature and During Testing

Meechai Sriwiboon, (Compact International (1994)).

Kritsana Kaewlob, (Compact International (1994)).

Seong Rhee, (SKR Consulting).

EB2020-STP-038

FE-Modeling for Brake Squeal Simulation with Uncertain Parameters

Michael Klein, (INTES).

17–17:30 CEST Meet the Speakers

15:00–16:40 CEST Technical Sessions

IBR – Innovative Brake Rotors

Chair: Marko Tirovic, Cranfield University
Co-chair: Deaglán Ó Meachair, Brake Batter

EB2020-MDS-012

Metal-Ceramic Hybrid Brake Disc: Concept, Prototype, Testing

Thorsten Opel (né Balzer), Nico Langhof, Walter Krenkel, (University of Bayreuth).

EB2021-EBS-002

Topology Optimisation of an Automotive Disc Brake Rotor to Improve Thermal Performance and Minimise Weight.

Ahmed Oshinibosi, (School of Mechanical engineering).

David Barton, Peter Brooks, Carl Gilkeson, (University of Leeds).

EB2021-FBR-006

On Thermal Diffusivity of Selected Gray Cast Irons and its Impact on Friction Performance of Automotive Brakes

Rohit Jogineedi, Vishal Reddy Singireddy, Peter Filip, (Southern Illinois University Carbondale).

Sai Krishna Kancharla, (PureForge).

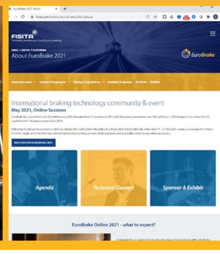
EB2021-STP-009

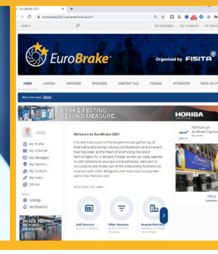
Universal Brake Disc Analysis with New High-speed Thermographic Systems for Automated Test Bench Solutions

Steffen Sturm, (InfraTec).

17–17:30 CEST Meet the Speakers

Please visit our sponsors:




Monday, 17 May 2021 (cont.)

17:30–19:30 CEST Posters

Chair: David Barton, University of Leeds. Chair: Parimal Mody, Automotive Brake and Friction Expert

EB2020-EBS-007
Gear Optimization for Noise Reduction of EPB Actuator *Sangbum Kim, Inuk Park, Changhun Park, (Hyundai Mobis).*

EB2020-FBR-015
Simulation Studies of a Ventilated Brake Disc With Variable Friction Plate Thickness *Qianjin Yang, (Yantai Winhere Auto-Part Manufacturing). Fulin Gai, Hui Yu, Liqiang Song, Baozhi Zhang, (Yantai Winhere Auto-Part Manufacturing).*

EB2020-IBC-015
Terra Dura™ – 100% Sealed Dry Disc Brakes; Helping to Create a Sustainable Braking Future *Tony Van Litsenborgh, Guy Hainsworth, (Advanced Braking Technology).*

EB2020-MDS-007
Parameter Identification of Mechanical Properties of Anisotropic Friction Materials *LiangLiang Liu, Huajiang Ouyang, (University of Liverpool). Jibran Bamber, Max Chowanietz, Efe Tunc, (Jaguar Land Rover).*

EB2020-MDS-030
Studying the Influence of the 3rd-body Formation on the Tribological Properties of High Performance Friction Materials *Felix Wich, Nico Langhof, Walter Krenkel, (University of Bayreuth).*

EB2020-STP-004
Mode Split Brake Disc Design Optimization for Squeal and Thermal Judder *Jinghan Tang, Jibran Bamber, (Jaguar Land Rover).*

EB2020-STP-005
Brake Rotor Vane Modification Effect in the Enhancement of Heat Transfer for Heavy Duty Vehicles *Dilek Bayrak Akça, Öznur Çetin, Yasin Hacısalihoğlu, (Ford Otosan). Ibrahim Can Guleryüz, Barış Yılmaz, (Ege Fren).*

EB2020-STP-010
Operational Bending and Torsion of a Vehicle Body Under Brake Judder Loads *Juan J. Garcia, Bernat Ferrer, Fabio Squadrani, (Applus IDIADA).*

EB2020-STP-049
Preliminary Study on Developing a Methodology of Friction Behaviour under Extremely Low Sliding Speed *Aihong Li, Kang Li, Jianguo Zhang, Janghong Long, Otto Schmitt, (Zhuhai Glory Friction Material).*

EB2020-STP-051
Streamlining Brake Squeal DOE Simulations *Ioannis Karypidis, (BETA CAE Systems). Federico Zaramella, (BETA CAE Italy Srl).*

EB2021-EBS-005
Investigation of Tribological Behavior and Airborne Emissions During the Bedding Stage *Ana Paula Gomes Nogueira, Stefano Candeo, Giovanni Straffelini, (University of Trento). Eng. Mara Leonardi, (Brembo).*

EB2021-EBS-010
Mechanism of Particles Released into the Environment That Is Formed by Brake Wear on Friction Surfaces *Saša Vasiljević, (Academy of Professional Studies Šumadija, Department in Kragujevac). Jasna Glišović, Nadica Stojanović, Ivan Grujić, (University of Kragujevac, Faculty of Engineering).*

EB2021-MDS-005
Design and Development of Brake Caliper using Additive Manufacturing *Swapnil Kumar, (University of Louisville). Thundil Karuppa Raj Rajagopal, (Vellore Institute of Technology, Vellore).*

EB2021-STP-008
Numerical Modelling of Composite Brake Pad Operational Deflection Shapes *Mohammad Ravanbod, (University of Bradford).*

EB2021-IBC-008
Brake Actuation & Foundation Trends Driven by Electrification & Autonomous Driving *Patricio Barbale, (ihs markit).*

EB2020-MDS-004
LMD & High-Speed Laser Cladding – Perspectives for Brake Discs *Sabrina Vogt, Marco Göbel, Florian Hermann, (TRUMPF Laser- und Systemtechnik).*

EB2021-STP-017
Automatic Pad Thickness Variation Tester
Seung Bok Kim, (Sun Bee Instruments).

EB2021-STP-018

Test Bench Brake Calliper with Maximum Power Range
Armin Diller, Jürgen Gaßner, (RENK Test System).

Tuesday, 18 May 2021

11:00–12:40 CEST Technical Sessions

BCE – Brakes and Components in EV

Chair: Tobias Ell, EvoBus
Co-chair: Hans-Jörg Feigel, Mando Halla

EB2020-IBC-006

ACHILES-Project – Requirements and Design Recommendations for Optimized Wheel Brakes of Battery Electric Vehicles

Sebastian Gramstat, Stefan Heimann, Christopher Hantschke, (Audi). Paul Linhoff, Sebastian Müller, (Continental Teves). Oliver Biewendt, Michael Lingg, (VW).

EB2020-STP-006

Development of a Thermal Simulation Tool for Early Sizing of Nonstandard Brake Concepts *Gerrit Nowald, Benjamin Siegl, (Continental Teves).*

EB2020-IBC-011

Brake-by-Wire Technology for Future Generations of Battery Electric Vehicles – the EVC-1000 Project

Sebastian Gramstat, Stefan Heimann, Martin Angel, (Audi).

Matteo Mazzoni, Beniamin Szewczyk, (Brembo S.p.A.).

EB2020-IBC-025

Vehicle Impacts Introducing Electromechanical Brakes

Daniel Herven, Anders Nilsson, (Haldex Brake Products AB).

EB2020-STP-064

Simulation of Regenerative Brake Blending Using Hardware-in-the-Loop on an Inertia Dynamometer

Carlos Agudelo, Marco Zessinger, (Link). David Antanaitis, (GM). Michael Peperhowe, (dSPACE).

13–13:30 CEST Meet the Speakers

11:00–12:40 CEST Technical Sessions

FOF – Fundamentals of Friction

Chair: Philippe Dufrénoy, University Lille
Co-chair: Kai Bode, Audi

EB2021-FBR-008

Particles Emissions and Understanding the Braking Tribological Circuit

Edouard Davin, Laurent Coustenoble, Yannick Desplanques, (Centrale Lille). Arnaud Beaurain, (University Lille).

EB2021-FBR-009

Relationship between Mechanical Behavior and Microstructure Evolution of Sintered Metallic Brake Pad under the Effect of Thermomechanical Stresses

Hoang Long Le Tran, Anne-Lise Cristol, (École Centrale de Lille). Vincent Magnier, (Ecole Polytech Lille). Jérôme Hosdez, (University Lille).

EB2020-FBR-038

Multi-physics Experiments and Numerical Simulation Highlighting the Role of Contact Surface Evolution on Squeal Occurrence

JeanFrancois Brunel, (LaMCube Univ Lille). Van-Vuong Lai, Philippe Dufrenoy, (LaMCube). Igor Paszkiewicz, (Paszkiewicz). Maxence Bigerelle, (LAMIH).

EB2021-FBR-001

A Comparison between Stationary and Dynamic Wear Tests of Brake Pads

Jacek Kijanski, Georg-Peter Ostermeyer, (TU Braunschweig).

EB2021-STP-007

Adhesion-related Wear Dust Transport

Georg-Peter Ostermeyer, (TU Braunschweig). Chengyuan Fang, Felix Rickhoff, (TU Braunschweig).

13–13:30 CEST Meet the Speakers

14:00–15:40 CEST Technical Sessions

EFF – Environmentally Friendly Formulations

Chair: Sylvie Descartes, INSA-Lyon
Co-chair: Raffaele Gilardi, Imerys Graphite & Carbon

EB2021-MDS-007

Friction Materials: Best Practices for the Evaluation of Corrodibility and Corrosion Mechanism

Federico Bertasi, Marco Bandiera, Arianna Pavesi, Andrea Bonfanti, Alessandro Mancini, (Brembo S.p.A.).

EB2020-FBR-013

Wear Debris Emissions and Antimony Trisulfide Tribochemistry

Roberto Dante, Edoardo Cotilli, Michael Conforti, Mario Cotilli, (Quartz S.r.l.s.u.).

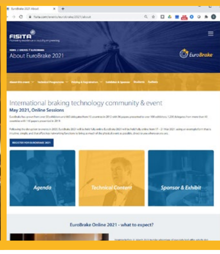
John Oleary, (Applus IDIADA).

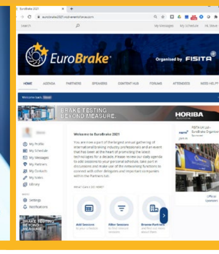
EB2021-MDS-009

Enhanced Performance of Eco-friendly Brake-pads by Using Plasma Treated Metallic Particles

Navnath Kalel, Jayashree Bijwe, Ashish Darpe, (IIT Delhi).

16–16:30 CEST Meet the Speakers




Rail Technical Programme

Tuesday 18 May 2021 (cont.)

Rail Keynote

09:00–10:15 CEST

What can the automotive braking community learn from rail, and vice versa? Thoughts about electric cars and autonomous driving

Stefan Dörsch*, Head of CoC brakes, couplings, door-systems, DB Systemtechnik, Germany*

Chair: Jan Münchhoff, AUDI

The global automotive industry is facing major challenges on a range of topics, including several technical issues which are well known to the railway sector. This presentation aims to provide a short overview of techniques and general principles in the railway sector which could act as the basis for potential further collaborations between the two sectors.

In terms of brake management, the sophisticated interaction between a conventional braking system and the use of the traction motor as a generator is an essential factor. The hierarchical interaction of different braking systems, including electro-dynamic, regenerative braking is well established in the railway industry, and a case study of DB AG's ICE 3 will be used to illustrate this interaction.

Since the introduction of signalling systems, railway operation has been externally-controlled, with a strong link to the braking performance of trains. When it comes to autonomous driving, the automotive braking community will face the same challenges. In the rail sector, the organisation of train movements over the track is classically regulated, typically controlled by optical signals. The most up to date version of the European Train Control System (ETCS) requires no signals and limited trackside equipment, enabling the automated driving of trains.

This presentation will provide an overview of the technical principles and safety requirements for such a system, and then focus on the retroactive effects on train brake control, which must meet the objective of robust and optimised operational control. The reproducibility of braking distances under a wide range of weather conditions, for example, plays a major role here.

Braking in the railway sector is closely connected to the guiding of trains along the track, and there are opportunities to explore parallels with automated vehicles.

Finally, daily brake performance testing is a long-established practice in the rail sector, to determine the continuity of the brake control line as well as the readiness of individual brake generating elements. In principle, similar procedures will be required for autonomous driving in the absence of a driver carrying out legally required brake checks.

The presentation will conclude with a dialog between braking specialists in the railway sector with those in the automotive sector, in order to benefit both sectors.

14:00–15:40 CEST Technical Sessions

IBB – Intelligent Braking and Braking Control (Rail)

Chair: Stefan Dörsch, DB Systemtechnik
Co-chair: Johannes Gräber, Knorr-Bremse

EB2021-MFM-003

Railway Brake System in Nordic Countried Application in Sweden's Challenges and Constrains

Denis Emorine, (ALSTOM).

EB2021-IBC-007

METROFLEXX: a step towards a safer railways brake control

Fabio Ferrara, Astengo Federico, Matteo Frea, (WABTEC CORPORATION).

EB2021-STP-019

Performance Evaluation for Wheel Slide Protection System with Factor Analysis in Simulation

Daisuke Hijikata, (Railway Technical Research Institute).

EB2021-STP-003

Benchmarking the Adaptive Wheel Slide Protection

Luc Imbert, Matteo Frea, (Wabtec).

EB2021-IBC-011

Application of UIC 421 procedure to Freight Trains fitted with a Distribute Power System

Luciano Cantone, (University of Rome "Tor Vergata"). Robert Karbstein, (DB Systemtechnik).

16–16:30 CEST Meet the Speakers

Preliminary Technical Programme

Tuesday 18 May 2021 (cont.)

16:30–18:30 CEST Technical Sessions

ISO – ISO

Chair: Mr. Harald Abendroth, Consultant
Co-chair: Jaroslaw Grochowicz, Ford

EB2020-MDS-005

Road Vehicles – Friction-related Characteristics and Test Methods for Brake Discs

Sebastian Gramstat, (Audi). Carlos Agudelo, (Link).

EB2020-MFM-007

Standardization of Drag Mode Friction Test for Hydraulic and Pneumatic Vehicle Brakes *Nicolae Penta, (TMD Friction Romania).*

EB2021-MFM-002

"Road Vehicles – Brake Linings Friction Materials – Visual Inspection" – ISO DIS Upgrade *Andreas Jandl, (VRI – Verband der Reibbelagindustrie e.V.).*

EB2020-MFM-013

ISO 6310 Compressive Strain Test Methods *Carlos Agudelo, (Link).*

EB2020-STP-063

SAE Standards Update *Carlos Agudelo, (Link).*

EB2020-EBS-009

JSAE Standardization Activities Update

Masaki Hayakawa, (Akebono Brake Industry). Shigeru Sakamoto, (Toyota Motor). Masato Yamaguchi, (Nissan Motor). Yuzo Todani, (Mazda Motor). Naoki Hata, Tatsushi Ishikawa, (ADVICS.).

Discussion: ***Do we need new standard test procedures, obsolete old procedures?***
Wrap-up

Wednesday, 19 May 2021

09:00–10:40 CEST Technical Sessions

BEM1 – Brake Emissions Macroscopic Part 1

Chair: Theodoros Grigoratos, European Commission, Joint Research Centre
Co-chair: Parimal Mody, Automotive Brake and Friction Expert

EB2021-EBS-003

Influence of the Run-in Methodology on the Particle Number Emission of Brakes

Katharina Kolbeck, (BMW/ TU Ilmenau). Matthias Bernhard, Thomas Schröder, (BMW). David Hesse, Klaus Augsburg, (TU Ilmenau).

EB2021-FBR-002

Study on the Brake Particle Emissions of Various Friction Materials

Shotaro Imai, Katsuya Okayama, Koji Sugimoto, Noriko Matsunaga, (ADVICS.).

EB2020-STP-018

Experimental Validation of the PMP Air Cooling Adjustment for Brake Emissions Measurements

Carlos Agudelo, (Link). Eng. Ravi Teja Vedula, Quinn O'Hare, (Link). Eng. Jaroslaw Grochowicz, (Ford Werke). Theodoros Grigoratos, (European Commission, Joint Research Centre).

EB2020-FBR-019

Investigation of Brake Wear Particle Emissions from Different Disc Brake Friction Components and Urban Driving Cycles Using a JASO C 470 Methodology.

Hiroyuki Hagino, (Japan Automobile Research Institute).

11–11:30 CEST Meet the Speakers

09:00–10:40 CEST Technical Sessions

MMD – Materials, Manufacturing and Design (rail)

Chair: Jiliang Mo, Southwest Jiaotong University
Co-chair: Tim Hodges, DRiV

EB2021-FBR-004

The Effects of Structural Stiffness in Vibration Transmission Paths on Friction-Induced Vibration

Qiang Liu, Jiliang Mo, Zaiyu Xiang, Anyu Wang, Wei Chen, Honghua Qian, (Tribology Research Institute Southwest Jiaotong University Chengdu 610031, P. R. China).

EB2021-EBS-011

Railway Squealing Noise on Nordic Trains Application in Sweden.

Denis Emorine, (ALSTOM).

EB2021-STP-016

Performance of Non-segmented and Segmented Railway Brake Discs – Temperatures, Wear and Fatigue Investigated by Field Experiments and Simulations

Eng. Mandeep Singh Walia, Bjarke Raaby, (Green Cargo AB). Eng. Gaël Le Gigan, (Volvo Car Corporation). Eng. Tore Vernersson, Roger Lundén, (Chalmers University of Technology).

11–11:30 CEST Meet the Speakers

Thursday, 20 May 2021

11:30–13:10 CEST Technical Sessions

BEM2 – Brake Emissions Macroscopic Part 2

Chair: Guido Perricone, Brembo S.p.A.
Co-chair: Sebastian Gramstat, Audi

EB2020-EBS-038

Real-World Brake-Wear Emission Factors – California's Perspective *Carlos Agudelo, (Link). Jeff Long, Seungju Yoon, Sam Pournazeri, Jorn Herner, Sonya Collier, (CA Air Resources Board (CARB)). Alan Stanard, Sandeep Kishan, (Eastern Research Group (ERG)). Ravi Vedula, Radoslaw Markiewicz, (Link). Simon Bisrat, Jason Lee, (CA Department of Transportation (Caltrans)). Chad Bailey, Michael Aldridge, Michael Hays, Bob Giannelli, Darrell Sonntag, Jeffrey Stevens, (U.S. Environmental Protection Agency (U.S. EPA)).*

EB2021-EBS-004

Influence of Pad Retraction and Air Gap Width between Brake Disc and Pad on PM10 Wear Emissions During Cruising Conditions *Hartmut Niemann, Hermann Winner, (TU Darmstadt). Christof Asbach, Heinz Kaminski, (Institute of Energy and Environmental Technology). Georg Frentz, (Daimler AG).*

EB2021-EBS-006

Investigation of Particle Dynamics with Real Vehicles and Swarm Sensors

Georg-Peter Ostermeyer, (TU Braunschweig, institute of dynamic and vibrations). Malte Sandgaard, Guido Lehne-Wandrey, (Institute of Dynamic and Vibration).

EB2021-STP-004

IT-Dimensions of Swarm-based Measurement of Particulate Matter

Guido Lehne-Wandrey, Jan Malte Sandgaard, Georg-Peter Ostermeyer, (TU Braunschweig).

14–14:30 CEST Meet the Speakers

11:30–13:10 CEST Technical Sessions

NVHV – NVH Vehicle Applications

Chair: Jay Fash, Zoox
Co-chair: Torsten Treyde, ZF Group

EB2021-STP-011

Psychoacoustic Characteristics of Non-Linear Automotive Disk Brake Creep Groan

Severin Huemer-Kals, Máté Tóth, Dominik Angerer, Manuel Pürscher, Federico Coren, (Institute of Automotive Engineering, Graz University of Technology).

Jurij Prezelj, (University of Ljubljana).

Martin Zacharczuk, (Mercedes-Benz AG).

EB2020-STP-008

Considerations about the Interaction between Brake Creep Groan and Squeal in Disc Brakes

Narcís Molina Montasell, Juan Jesús García Bonito, Amadeu Martorell Branchat, Fabio Squadrani, (Applus IDIADA).

EB2021-STP-015

Brake Noise Detection Using Artificial Intelligence

Fabio Squadrani, Danilo Mendes Pedroso, Kenneth Mendoza, Eng. Juan J. Garcia Bonito, Juan Pablo Barles, Antonio Rubio, Antonio Jesus Contreras, Jose Francisco Martinez, (Applus IDIADA).

EB2020-STP-003

Brake Squeal Prediction Using Deep Learning

Merten Stender, Nadine Jendrysik, Daniel Schoepflin, Norbert Hoffmann, (Hamburg University of Technology).

David Spieler, (University of Applied Sciences Munich).

Merten Tiedemann, (Audi).

14–14:30 CEST Meet the Speakers

09:00–10:40 CEST Technical Sessions

NVHF – NVH Fundamentals

Chair: Jean-François Brunel, University Lille
Co-chair: Ho Jang, University of Korea

EB2020-STP-017

Experimental and Numerical Investigation of C/C Material Unstable Friction-Induced Vibration

Alessandro Lazzari, Simona Totaro, Davide Tonazzi, Francesco Massi, (University of Rome "La Sapienza").

Aurélien Saulot, (INSA-Lyon).

EB2021-STP-021

Investigation of Disc Brake Pad Interface Pressure Distributions Using FBG Sensors

Zicheng Wang, Steve James, Marko Tirovic, (Cranfield University).

EB2020-STP-058

A Study on Brake Squeal Focusing on the Relationship Between Mode Coupling and Curve Veering

Hayuru Inoue, (Hitachi Automotive Systems,).

EB2021-STP-006

Structured Light 3D Sensor for Fast and High Precision Surface Dynamics Measurements

Georg-Peter Ostermeyer, (TU Braunschweig).

Chengyuan Fang, Guido Lehne-Wandrey, Malte Sandgaard, Alexander Vogel, Jacek Kijanski, (Institute of Dynamics and Vibration of TU Braunschweig).

Thomas Hillner, Fabian Repetz, (wenglor sensoric).

11–11:30 CEST Meet the Speakers

Thursday, 20 May 2021 (cont.)

09:00–10:40 CEST Technical Sessions

STP – Simulation, Testing, Innovative Development Processes (rail)

Chair: Raphael Pfaff, FH Aachen
Co-chair: Roberto Tione, Wabtec-Faiveley

EB2021-FBR-005

Nonlinear Dynamic Analysis of CRH5 Disc Brake System

Quan Wang, Zhiwei Wang, Jiliang Mo, (Tribology Research Institute Southwest Jiaotong University Chengdu 610031).

EB2021-IBC-003

Simulation of Big Data from Railway Braking

Simon Westfechtel, (FH Aachen University of Applied Sciences). Ingo Elsen, Raphael Pfaff, Marcel Remmy, (FH Aachen).

EB2021-IBC-004

Braking Curves in Railway Shunting and Implications for the Development of Sensor Systems for Autonomous Shunting

Matthias Blumenschein, (FH Aachen University of Applied Sciences). Raphael Pfaff, Katharina Babilon, (FH Aachen).

EB2021-STP-010

Influence of System Boundary Condition on the NVH Behaviour of Bogie Brake Simulation

Georg-Peter Ostermeyer, Andreas Krumm, Frank Schiefer, (TU Braunschweig, Institute of Dynamics and Vibrations). Sebastian Montua, (Faiveley Transport Bochum).

EB2021-STP-022

Acoustic Certification of New Composite Brake Blocks

Stefan Doersch, Maria Starnberg, Haike Brick, (DB Systemtechnik).

14–14:30 CEST Meet the Speakers

11:30–13:10 CEST Technical Sessions

BEML – Brake Emissions Microscopic Level

Chair: Yezhe Lyu, Lund University (LTH)
Co-chair: Hiroyuki Hagino, Japan Automobile Research Institute

EB2020-EBS-031

Novel Approaches for Physico-Chemical Characterization of Brake Emissions

Alessandro Mancini, Sonia Pin, Bozhena Tsyupa, Federico Bertasi, Marco Bandiera, Matteo Federici, Andrea Bonfanti, Guido Perricone, (Brembo S.p.A.).

Ezio Bolzacchini, (University of Milano Bicocca).

EB2021-STP-002

Development of a Small-scale Test Bench for Investigating the Tribology and Emission Behaviour of Novel Brake Friction Couples

Fabian Limmer, David Barton, Anne Neville, Peter Brooks, Shahriar Kosarieh, (University of Leeds).

EB2021-STP-005

The Variable Velocity Tribotester

Georg-Peter Ostermeyer, Alexander Vogel, Jacek Kijanski, Malte Sandgaard, Guido Lehne-Wandrey, (TU Braunschweig).

EB2021-STP-013

Particle Simulation and Metrological Validation of Brake Emission Dynamics on a Pin-on-Disc Tribotester

Sven Brandt, Arno Kwade, Carsten Schilde, (TU Braunschweig, Institute of Particle Technology).

Malte Sandgaard, Georg-Peter Ostermeyer, (Institute of Dynamic and Vibrations).

Sebastian Gramstat, (Audi).

Frank Stebner, Conrad Weigmann, (VW).

14–14:30 CEST Meet the Speakers

EuroBrake meets Shift2Rail

14:00–15:40 CEST Thursday 20 May

Chairs:
Johannes Gräber, Knorr-Bremse
Roberto Tione, WABTEC-Faiveley

For the first time in 2021 we will hold a Rail Panel "EuroBrake meets Shift2Rail" to establish a closer cooperation with the major European Research Program Shift2Rail (https://shift2rail.org/).

Shift2Rail wil be introduced by **Carlo Borghini, Executive Director of the European Shift2Rail Joint Undertaking**, with a focus on the evolution of automation in the European railway systems in order to maximize the performance of the current infrastructure in terms of capacity, lifecycle cost reductions and punctuality. In this respect, railway automation and digitalization rely on the performance and contributions of critical subsystems, where the braking systems have a major role. The R&I work started with a bottom-up technological approach in S2R has evolved during the years with the introduction of a system integrated approach, to ensure that all critical elements deliver together a functional performance that will contribute to deliver sustainable mobility, with rail playing a major role.

Three technical presentations (see next column) and a Roundtable discussion will follow the introduction.

14:00–15:40 CEST Technical Sessions

ESR – EuroBrake meets Shift2Rail

Chair: Johannes Gräber, Knorr-Bremse
Co-chair: Roberto Tione, WABTEC-Faiveley

EB2021-IBC-009

Safe Deceleration Recovery in Degraded Braking Conditions

Matteo Frea, Luc Imbert, (Wabtec).

EB2021-IBC-010

Concept for Reproducible Braking Distance

Michael Kohl, (Knorr Bremse SfS).

Christopher Lozano, (Knorr Bremse Systeme für Schienenfahrzeuge).

EB2021-MFM-004

The Digital Freight Train and Associated Use Cases

Antoine Rothey, (Fret SNCF).

EB2021-MFM-005

Introduction to Shift2Rail

Carlo Borghini, (Shift2Rail Joint Undertaking).

Roundtable follows presentations

Please visit our sponsors:

Friday, 21 May 2021

09:00–10:40 CEST Technical Sessions

BCN – Brake Control

Chair: Manfred Meyer, ZF Group
Co-chair: Claudio Prina, IVECO

EB2020-IBC-019

Characterisation of the Objective Metrics Defining an Adaptive Cruise Control (ACC) and Comparison with the Subjective Assessment of Its Performance

Bernat Ferrer, (Applus IDIADA).

EB2021-IBC-002

Analysis of Safety Relevant Wheel Individual Brake Torque Requirements for City EVs

Tobias Loss, Simon Peter, Armin Verhagen, (Robert Bosch).

Daniel Görges, (Technische Universität Kaiserslautern).

EB2021-IBC-006

Requirements and Test Cycles for Brake Systems of Autonomous Vehicle Concepts on the Example of an Autonomous Shuttle

Lennart Guckes, Hermann Winner, (TU Darmstadt Institute of Automotive Engineering (FZD)).

Jens Hoffmann, Sébastien Pla, (Continental Teves).

EB2020-IBC-016

Current Limits of Virtual Development for Brake Controls

Joachim Noack, (ZF Passive Safety).

EB2020-STP-068

Designing Regenerative Brake Control Algorithms Using Simulation

Steve Miller, Jan Janse van Rensburg, (MathWorks).

11–11:30 CEST Meet the Speakers

09:00–10:40 CEST Technical Sessions

IRM – Innovative Raw Materials

Chair: Eros Sales, ITT Motion Technologies
Co-chair: Fernao Persoon, Lapinus

EB2020-MDS-003

Correlation between Friction Performance and Tribolayer Formation Using Engineered Mineral Fibres

Neomy Zaquen, Arno Kerssemakers, Fernao Persoon, (Lapinus).

EB2020-MDS-036

Spherical Molybdenum Disulfide (SMD) in Brake Pads Applications

Yakov Epshteyn, Lawrence Corte, (Climax Molybdenum).

EB2021-FBR-003

Determination of the Influence of Metal Sulphides on the Tribofilm and the Friction Behavior

Gabriela Macías, Carlos Lorenzana, (Rimsa Metal Technology S.A).

Javier Fernandez, (University of Barcelona).

EB2021-MDS-004

The Effect of Chopped Steel Fibre Orientation on Frictional Properties in a Phenolic Resin-based Asbestos-free Semimetallic Friction Material

M.A. Sai Balaji, Eakambaram Arumugam, (B S Abdur Rahman Crescent Inst. of Science & Technology).

S. Habib Rahmathulla, H. Sultan Navid, (Indian Friction Material Engineering Company).

P. Baskara Sethupathi, (SRM Institute of Science and Technology).

11–11:30 CEST Meet the Speakers

Friday, 21 May 2021 (cont.)

12:00–13:40 CEST Technical Sessions

ART – Advances in Rotor Technology

Chair: David Bryant, University of Bradford
Co-chair: Enda Claffey, Bentley

EB2021-MDS-002

Alumina-coated Brake Discs with Intention for Reduced Non-exhaust Emission and Increased Ride Comfort of Electrical Vehicles

Xueyuan Nie, (University of Windsor).

Ran Cai, Jingzeng Zhang, (University of Windsor).

Jimi Tjong, (Ford of Canada).

EB2021-MDS-012

The Prospects of Lightweight SICAlight Discs in the Emerging Disc Brake Requirements

Eng. Samuel Awe, Adam Thomas, (Automotive Components Floby AB).

EB2020-STP-057

Physical Background for Experimental Brake Disc Identification

Peter Blaschke, Daniel Alarcon, (TH-Wildau).

14–14:30 CEST Meet the Speakers

12:00–13:40 CEST Technical Sessions

HPP – High Performance Products

Chair: Andrew Smith, Alcon Components
Co-chair: Alessandro Monzani, Brembo S.p.A

EB2020-EBS-017

Design and Optimization Method for a High Power Eddy Current Brake with a Magneto-isotropic Material Structure for the Use in Electrified Heavy Duty Trucks

Christoph Holtmann, (German Aerospace Centre (DLR)).

EB2020-STP-065

State of Art Brake Systems in Motorsport

David Clegg, Garry Wiseman, Andrew Smith, (Alcon Components Limited).

EB2020-STP-069

Potential and Challenges for Application-specific Friction Characteristics of Race Brake Pads

Xabier Ugarte, Jürgen Voigt, (TMD Performance).

Daniel Heiderich, (HRW Hochschule Ruhr West, Institut Maschinenbau).

14–14:30 CEST Meet the Speakers

Sponsor Packages Still Available at £3,685

- *Premium EuroBrake Directory listing*
- *2021 Event Virtual Exhibit & networking*
- *Sponsor presentation in Content Hub*
- *Promotion within technical sessions*
- *Logo accreditation*
- *Advertising package*
- *Branding on event highlights content*

Please email sales@fisita.com to book

Please visit our sponsors:

Please visit our sponsors:

EB2021-EBS-010

MECHANISM OF PARTICLES RELEASED INTO THE ENVIRONMENT THAT IS FORMED BY BRAKE WEAR ON FRICTION SURFACES

Saša Vasiljević[1 *] , Jasna Glišović [2] , Nadica Stojanović[3] , Ivan Grujić[4]

[1]*Academy of Professional Studies Šumadija, Department in Kragujevac*
Kosovska 8, 34000, Kragujevac, Serbia (E-mail: name@thi.de)
[2]*University of Kragujevac, Faculty of Engineering*
Sestre Janjić 6, Kragujevac 34000, Kragujevac, Serbia

DOI (FISITA USE ONLY)

ABSTRACT: Solving the problem of the formation of particles caused by the wear of the brakes' friction surfaces and their release into the environment is of utmost importance. Today, various technologies have been developed that aim to collect particles directly during braking or generation. With the aim of further development of devices and technologies in this paper, the modes and mechanisms of release of the formed particles into the environment are analyzed. Based on this review of the particle release mechanisms, further development of technologies for collecting particles that are a product of friction surface wear is enabled. The mechanisms of particle release are mainly reflected in the fact that they are released during the braking of the vehicle, then by releasing particles during the re-acceleration of the vehicle and the third way is falling of already formed particles from friction surfaces. In this paper, all three mechanisms are explained and analyzed in more detail.

KEY WORDS: Wear, brakes, particles, release.

1. INTRODUCTION

It is possible to find several unique definitions of particles in the professional literature. However, as a general conclusion of the term of particles, it can be said that particles are any solid or liquid substance in a finely divided state, which can be suspended in air, blown away by wind and can consist of a mixture of organic matter, inorganic matter, metals, carbon and other inorganic materials [1, 2, 3]… According to [4] particles and their fractions are the most harmful of all air pollutants. Particles can be of different sizes, less than 1 μm and larger than 100 μm [3], but the most commonly monitored particles are from 10 μm to 2.5 μm (PM_{10}), particles below 2.5 ($PM_{2.5}$) [5,6]. Sources of particles are numerous, and they are means of transport, industry, households, fires, [6,7]…

One of the important sources of particles on the vehicle is the braking system [8]. The braking system emits particles by wearing the elements of the friction pair, so these particles are called non-exhaust particles, bearing in mind that they are not formed by combustion, but by the wear of friction surfaces [9, 10]. According to the source [11], abrasive and adhesive wear of friction brake pads and brake discs most often occur. The problem in the case of brakes and their wear is that the friction elements often consist of metal, but also other harmful substances that can be dangerous to human health. According to [12], it was concluded that Fe, Cu, Si, Ba, K, Ti are the dominant elements in the particles formed by the wear of the brake pads.

Passenger vehicles today are mainly equipped with disc and drum brakes. Modern vehicles, mainly sports vehicles, are equipped exclusively with disc brakes. When it comes to particles generated by the brakes, the drum brakes are preferred, bearing in mind that formed particles are kept inside the drum, while only a small amount of the particles is released in the atmosphere after stopping the drum [13]. As for the disc brakes, they do not have a housing, as drum brakes, but the particles are released directly into the environment. Various technologies and modules have been developed that aim to collect the resulting particles caused by brake wear [14].

Having in mind the previously mentioned, the aim of this paper is to present and analyze different ways of releasing particles into the environment in the case of disc brakes. Such analysis and presentation can further assist in the development of particle collection systems on vehicles. Furthermore, this theoretical analysis is suitable for further experimental research and determination of the percentage share of each of the ways of releasing particles in the total emission of created particles.

2. BRAKE WEAR PARTICLE FORMATION

The formation of particles created by the wear of the brakes occurs by breaking the small irregularities on the friction surfaces. Such irregularities are a consequence of the imperfection of the microscopic surfaces of the friction pairs, which are in mutual contact during braking. Figure 1 shows the above-mentioned method of particle formation, as well as the braking process itself and the way in which the release of particles from the braking process occurs [15]. Figure 1b clearly shows the simulation of the microscopic surface of the friction pair and the way particles are formed by breaking small microscopic irregularities from the friction surfaces [16]. Of course, the fact must be taken into account that based on the results of the research of particles formed by the wear of friction elements [17], it can be concluded that the wear of brake pads is more dominant in relation to brake disc.

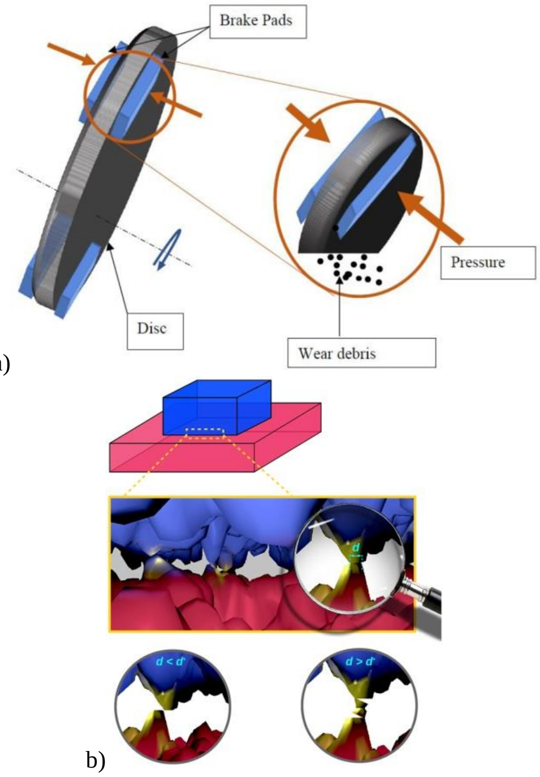


Figure 1: Brake wear mechanism: a) brake process and particle formation, b) micro mechanism of brake wear [15,16]

When it comes to disc brakes, particles' sizes are different, their appearance and a variety of sizes of these particles is best shown in the research [18], in Figure 2. It is noticeable that the particles differ in size and therefore, smaller particles have a much greater impact on human health.

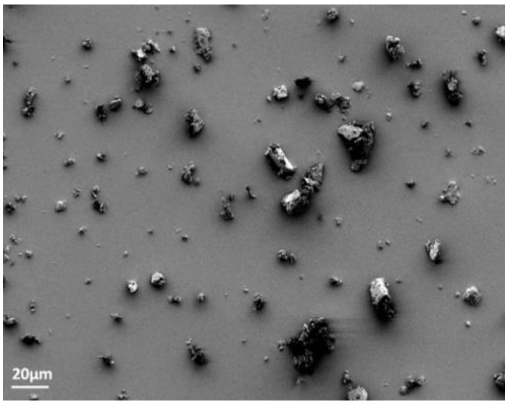


Figure 2 : Brake wear particles [18]

The reason and the manner of formation are described in the paper [9], where it was concluded that the formation of particles occurs due to the fracture of micro-roughness on the friction surfaces of the brakes. Such irregularities on the example of the brake friction element, which is enlarged, are shown in Figure 3. Irregularities and debris are clearly visible from the figure, which, after contact with another friction element, create the particle emission. It is important to note that in this case the friction surface of the brake pad after wear is shown [19].

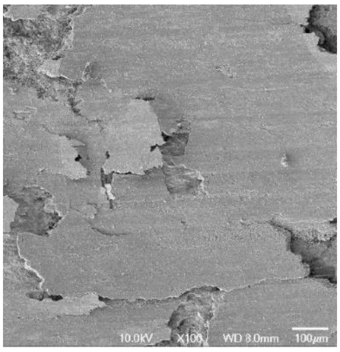


Figure 3 : Brake friction layer wear [19]

3. MECHANISMS OF PARTICLE RELEASE INTO THE ATMOSPHERE

The entire process of particle formation and release, which is presented in [20], clearly shows that during the action of the brake pad pressure, contact with the brake disc occurs. During this process, both elements of friction pair wear out, creating small fragments or particles. Thus, these particles are released from the brake surfaces and then further emitted into the atmosphere. A graphical representation according to the source [20] is shown in Figure 4. In this way, it is possible to understand the floating of particles in the air before its deposition on the ground.

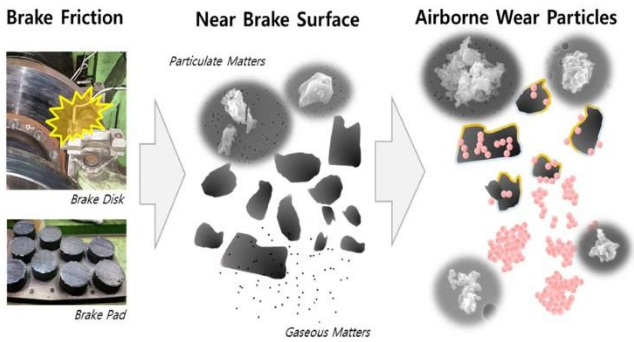


Figure 4 : Particle release [20]

The method of particle release into the environment can occur in three basic ways, which are explained and presented in more detail below:

- Release of particles during braking,
- Release of particles during re-acceleration of the vehicle,
- Release of particles when the vehicle is stationary - detachment of particles from the friction surfaces.

3.1. Release of particles during braking

This is the most basic and logical way to release particles. In this case, during braking, the particles are released precisely in the braking process, i.e. exactly when they are formed, or precisely in the case of brake wear. The angular velocity of the disc decreases, the pressure between the friction surfaces is greater than zero, so the particles in this case are released precisely in the process of braking, which is illustrated in Figure 5.

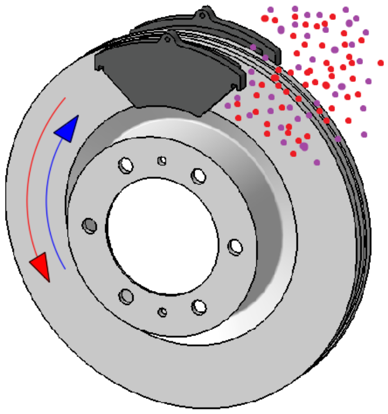


Figure 5 : Brake particles relese in braking process, where: blue arrow – angular speed of disc, red arrow – brake momentum

3.2. Release of particles during re-acceleration of the vehicle

In the research [13], it was concluded that after braking and during re-accelerating of the brake disc, particles are also released from the friction surfaces. Similar observations are made on the basis of research results [21]. The reason for this is that after the braking process, some of the particles remain on the brake disc and brake pads, so when the brake disc accelerates again and air flows through the friction surfaces, those particles that are not released during braking are subsequently released. A pictorial representation of this phenomenon is given in Figure 6.

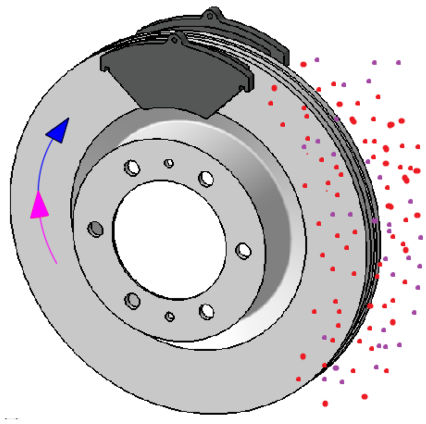


Figure 6 : Brake particles released in the acceleration process of disc (vehicle), where: blue arrow - angular speed of disc, pink arrow - disc acceleration

So, particles can be released during re-acceleration when the angular speed of the disc increases and there is no pressure between the friction linings, and these are particles that are not released in the braking process, but remain trapped or stuck inside the microscopic irregularities on the brake friction surfaces. It is important to note the fact that some of the particles trapped in the micro-roughness may remain there, so in the case of brake pad pressure they can compress and become part of a stable friction layer [22].

3.3. Release of particles during the state of rest of the vehicle - detachment of particles from the friction surfaces

The third case of particle release is the case when the vehicle is stationary. It has already been mentioned that during braking, some of the particles remain trapped in micro-roughness or remain "stuck" on the friction surfaces. During the state of rest, it is also possible for particles to be released if the particles detach from the friction surface, thus the particles from the friction surface fall to the ground and thus to the environment. Such phenomena can occur due to the influence of different climatic conditions, e.g. wind blowing or the influence of natural forces on the particles. Thus, in this case, the particles come off the friction surfaces and the particles fall to the ground or another surface on which the vehicle is parked. An example is shown in Figure 7, in this case it is clear that there is no pressure between the friction elements of the brake and the angular velocity of the brake disc is equal to zero but particles that are trapped or stuck on the friction pads are released or detached from the friction surface and fall to the ground.

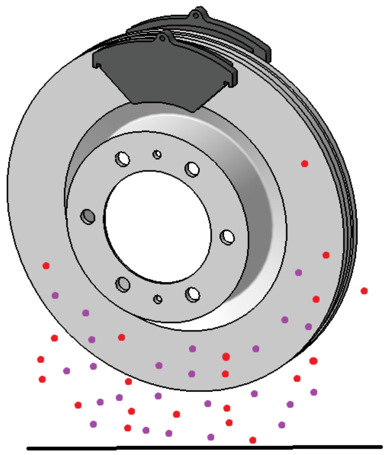


Figure 7 : Brake particles fall down on the ground from brake friction layer, where: black line – ground

4. CONCLUSION

In the future, the problem of brake wear will be one of the leading environmental pollutants, as one of the sources of particles on the vehicle. The formation of particles whose source is the braking system is associated with the breaking of micro-roughness on the friction surfaces of the brake. Such irregularities are broken by mutual contact. These broken pieces of micro-unevenness are, in fact, particles whose source is the braking system and which are released into the environment.

The release of particles into the environment, theoretically as in this paper, can occur during the process of braking and particle formation. Another way is to release particles that are trapped or stuck on the friction surfaces, and they are released when the disc is re-accelerated. The third case is the case of release or falling of particles from the friction surfaces of the brakes during a period when a vehicle is stationary, and due to the action of different climatic conditions or natural forces.

This theoretical analysis is very useful for reasons of further investigation, but also to take into account the way in which particles are released into the environment when designing and constructing the particle collection systems. When it comes to further research, such an analysis is useful for further research into the percentage and amount of particles released in each of these ways.

REFERENCES

[1] Olaguer P. Eduardo. Atmospheric Impacts of the Oil and Gas Industry, Elsevier, Boston, 2017.
[2] Rogoff Marc, Screve Francois. Permitting issues. Waste-to-Energy, 89–116, 2011.
[3] Acharya Bishnu. Cleaning of Product Gas of Gasification. Biomass Gasification, Pyrolysis and Torrefaction, 373–391, 2018.
[4] Donaldson, K., MacNee, W., Stone, V. Environmental pollutants Particulate Matter, Ultrafine Particles. Encyclopedia of Respiratory Medicine, 104–110, 2006.
[5] Kumar Rai Prabhat. Chapter One - Particulate Matter and Its Size Fractionation. Biomagnetic Monitoring of Particulate Matter, Elsevier, 1-13, 2016.
[6] Thurston D. George. Outdoor Air Pollution: Sources, Atmospheric Transport, and Human Health Effects. International Encyclopedia of Public Health, 367–377, 2017.
[6]El Morabet Rachida. Effects of Outdoor Air Pollution on Human Health. Reference Module in Earth Systems and Environmental Sciences, Elsevier, 2018.
[7] Fan, Z., Lin, L. Exposure Science: Contaminant Mixtures. Encyclopedia of Environmental Health, 645–656, 2011.
[8] Glišović J., Pešić R., Vasiljević S., Stojanović N., Grujić I. Road vehicle as a source of non-exhaust particulate matter, Proceedings of 14th International Conference on Accomplishments in Mechanical and Industrial Engineering DEMI 2019, Banja Luka, 2019, 24 - 25 May, pp. 585-590, ISBN 978-99938-39-85-9
[9]Vasiljević S., Glišović J., Stojanović B., Stojanović N., Grujić I. Composition of brake pads and influence factors affecting the wear intensity of the brake pads on vehicles, 8th International Congress Motor Vehicles & Motors 2020, October 8th - 9th, 2020, 117-122, ISBN 978-86-6335-074-8
[10]Kukutschová J., Filip P. Review of Brake Wear Emissions. Non-Exhaust Emissions,123–146, 2018.
[11]Vasiljević, J. Glišović, N. Stojanović, I. Grujić, Brake wear mechanism and particulate formation, Tractors and power machines, 2020, 25 (1/2):80-88
[12] Jadhav S. P., Sawant S. H. A. review paper: Development of novel friction material for vehicle brake pad application to minimize environmental and health issues. Materials Today: Proceedings 2019, 19 (2): 209-212.
[13] Hagino H., Oyama M., Sasaki S. Airborne brake wear particle emission due to braking and accelerating. Wear, 2015, 334-335:44–48.
[14]Vasiljević S., Glišović J., Stojanović N., Grujić I. Systems and technologies for reducing the particle emission whose source is wear of the vehicle brakes, Tractors and power machines, 2019, 24(1/2):82-89.
[15]Surya Rajan B., Sai Balaji M A., Baskar A. Correlation of test bench with actual vehicle condition of Indian commercial passenger cars, Proceedings of International conference on Advances in Industrial Engineering Applications- ICAIEA, 2018, 33-43.
[16]Fleischman Tom. 2016, Researchers simulate wear of materials as they rub together, available at: https://news.cornell.edu/stories/2016/06/researchers-simulate-wear-materials-they-rub-together, 05.12.2020.
[17]Mosleh M., Blau P. J., Dumitrescu, D. Characteristics and morphology of wear particles from laboratory testing of disk brake materials. Wear, 2004, 256(11-12):1128–1134.
[18]Selley L., Schuster L., Marbach H., Forsthuber T., Forbes B., Gant T. W., Sandström T., Camina N., Athersuch T. J., Mudway I., Kumar, A. Brake dust exposure exacerbates inflammation and transiently compromises phagocytosis in macrophages. Metallomics, 2020, 12(3):371–386.
[19] Lee J. J., Lee J. A, Kwon S., Kim J. J. Effect of different reinforcement materials on the formation of secondary plateaus and friction properties in friction materials for automobiles. Tribology International, 2018, 120:70–79.
[20] Namgung H.-G., Kim J.-B., Woo S.-H., Park S., Kim M., Kim M. S., … Kwon, S. B. Generation of Nanoparticles from Friction between Railway Brake Disks and Pads. Environmental Science & Technology, 2016, 50(7):3453–3461
[21] Chasapidis L., Grigoratos T., Zygogianni A., Tsakis A., Konstandopoulos A. G. Study of Brake Wear Particle Emissions of a Minivan on a Chassis Dynamometer. Emission Control Science and Technology, 2018, 4(4):271–278.
[22]Sinha A., Ischia G., Menapace C., Gialanella S. Experimental Characterization Protocols for Wear Products from Disc Brake Materials. Atmosphere, 2020, 11 (10):1102.